

## Radiation Effects Microscopy for First-Pass Success of an Application Specific Integrated Circuit (ASIC)

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**Motivation**—Most IC manufacturers – among them Sandia National Laboratories (Sandia) – rely on a standard cell library within a certain technology, which consists of a number of component circuits that can be used to implement various functions in that particular technology. The final product, be it a CPU or memory or other device, will be radiation hard if the components from the cell library are radiation hard. Usually these components are not individually tested but are designed to be radiation hard, either through the inherent circuit design or through process modifications (and often a combination of the two). Unfortunately, there are occasions when a component is found to be radiation sensitive in a complex circuit. A broad beam heavy ion test of an Application Specific Integrated Circuit (ASIC) recently showed an unexpectedly low single event upset (SEU) threshold (Fig. 1). To simulate the circuit response with a TCAD code is practically impossible because of the complexity of the IC; calculations would have to be performed for all of the standard cell circuits comprising the IC. In this case the Sandia nuclear microprobe was used to pinpoint the radiation-sensitive components.

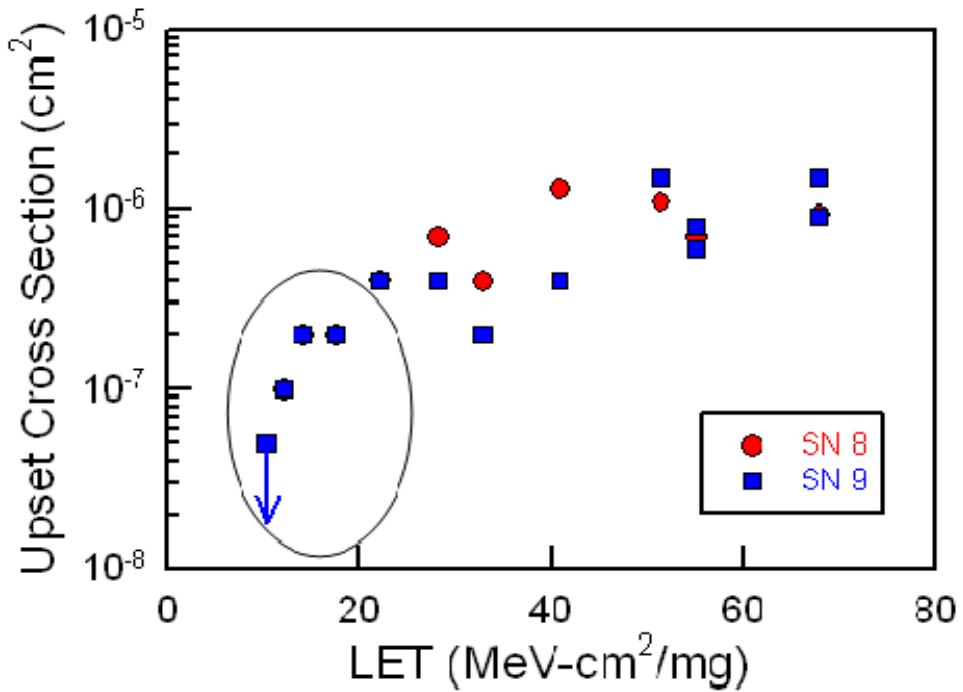
**Accomplishment**—SEU images were recorded of the regions of the circuit where the designers suspected more sensitivity to radiation. These measurements showed that a certain flip-flop structure that contained latches was responsible for the upsets. Unfortunately, because of the complexity of the circuit it was not possible to directly access the internal nodes of these structures. Therefore, the next step was to design test circuits that modeled the sensitive

components, in this case a number of the latch standard cells used in the library. A schematic diagram of one of these test circuits is shown in Fig. 2a. The structure contains transmission gates, and the TCAD (Davinci) calculations showed that the nodes at these transmission gates might be sensitive to heavy ion hits. Figure 2b shows the single event transient (SET) and ion beam induced charge (IBIC) maps overlaid on the GDS II map of the circuits. From this overlay we could clearly identify that the TCAD prediction was correct: the transmission nodes were sensitive to radiation. Removing the resistors from the circuits eliminated the SETs due to the ion hits at the transmission gate nodes. The irony in this is that the resistors were originally put in the circuit to make it more radiation hard. Unfortunately, although the resistors do increase hardness to certain strike locations, they decrease hardness to ion hits at the transmission gates. In addition to the sensitivity predicted by the TCAD code we found that the circuit was also sensitive to hits at the clock inverters, which had not been modeled. This sensitivity is still under investigation.

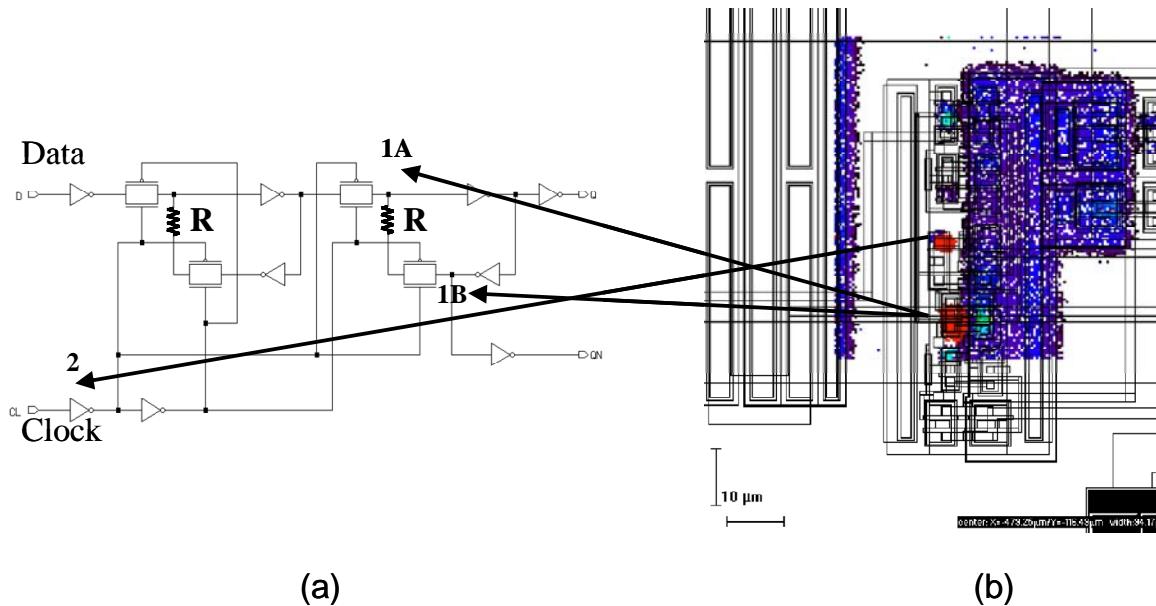
**Significance**—Components of the above cell library will be used in the technology used to make radiation hardened Pentium at Sandia. The use of the nuclear microprobe allowed us to pinpoint the radiation sensitive elements in this library, which led to the hardening of these components. This work helped the Microelectronics Development Laboratory (MDL) significantly accelerate the design and manufacturing process of the radiation hardened Pentium processor.

**Sponsors for various phases of this work include:** Nuclear Weapons/Readiness in Technical Base & Facilities

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**Figure 1.** SEU cross section of an Application Specific Integrated Circuit (ASIC).



**Figure 2.** (a) Schematic layout of the latch test structure. (b) SET (red) and IBIC (blue) images overplayed on the GDS II map of the latch structures. 1A and 1B show the transmission nodes where the circuit was sensitive to ion hits. This sensitivity disappeared after removing the **R** resistors, but the circuit is still sensitive to ion hits at location 2, at the clock inverter.